Cambridge Assessment International Education

# Cambridge IGCSE™

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*3901701282*

**CHEMISTRY** **0620/31**

Paper 3 Theory (Core) **October/November 2021**

**1 hour 15 minutes**

You must answer on the question paper.

No additional materials are needed.

**INSTRUCTIONS**

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

**INFORMATION**

- The total mark for this paper is 80.
- The number of marks for each question or part question is shown in brackets [ ].
- The Periodic Table is printed in the question paper.

This document has **20** pages. Any blank pages are indicated.


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**[Turn over**

**1** **(a)** A list of formulae is shown.

$AlCl_3$
$CaCO_3$
$CO$
$CO_2$
$CoCl_2$
$CuSO_4$
$MgCl_2$
$N_2$
$NaCl$
$NH_3$
$O_2$
$SO_2$

Answer the following questions using these formulae.
Each formula may be used once, more than once or not at all.

State which formula represents:

**(i)** a compound that changes colour from white to blue when water is added

..... [1]

**(ii)** a compound that is used to make cement

..... [1]

**(iii)** an element that forms 78% of clean, dry air

..... [1]

**(iv)** a compound that contains an ion with a single positive charge

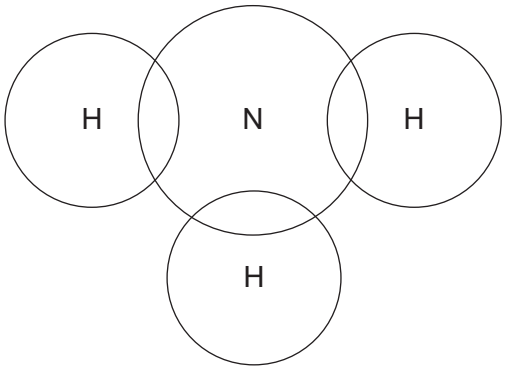
..... [1]

**(v)** a compound that dissolves in water to form an alkaline solution.

..... [1]

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**(b)** Complete the dot-and-cross diagram to show the electron arrangement in a molecule of ammonia.




[2]

**(c)** State whether magnesium oxide is a basic oxide or an acidic oxide.
Give a reason for your answer.

.....

..... [1]

[Total: 8]

**2** The table shows the masses of some of the ions in 1000 $cm^3$ of rainwater.

| name of ion | formula of ion | mass of ion in 1000 $cm^3$ of rainwater / mg |
|---|---|---|
| | $NH_4^+$ | 0.08 |
| calcium | $Ca^{2+}$ | 0.13 |
| chloride | $Cl^-$ | 1.30 |
| magnesium | $Mg^{2+}$ | 0.08 |
| nitrate | $NO_3^-$ | 0.70 |
| potassium | $K^+$ | 0.08 |
| sodium | $Na^+$ | 0.80 |
| | $SO_4^{2-}$ | 1.60 |

**(a)** Answer these questions using only the information in the table.

**(i)** State which of the positive ions has the highest concentration.

..... [1]

**(ii)** Name the compound containing $NH_4^+$ and $SO_4^{2-}$ ions.

..... [1]

**(iii)** Calculate the mass of magnesium ions in 400 $cm^3$ of rainwater.

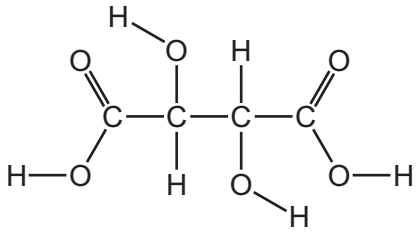
mass = ..... mg [1]

**(b)** Describe a test for chloride ions.

test .....

observations .....
[2]

**(c)** Small amounts of carboxylic acids are also present in rainwater.
The structure of tartaric acid is shown.



**(i)** On the structure draw a circle around one alcohol functional group. [1]

**(ii)** Deduce the formula of tartaric acid to show the number of carbon, hydrogen and oxygen atoms.

..... [1]

**(d)** Tartaric acid can be converted into compound **A**.
The formula of compound **A** is $C_3H_4O_3$.

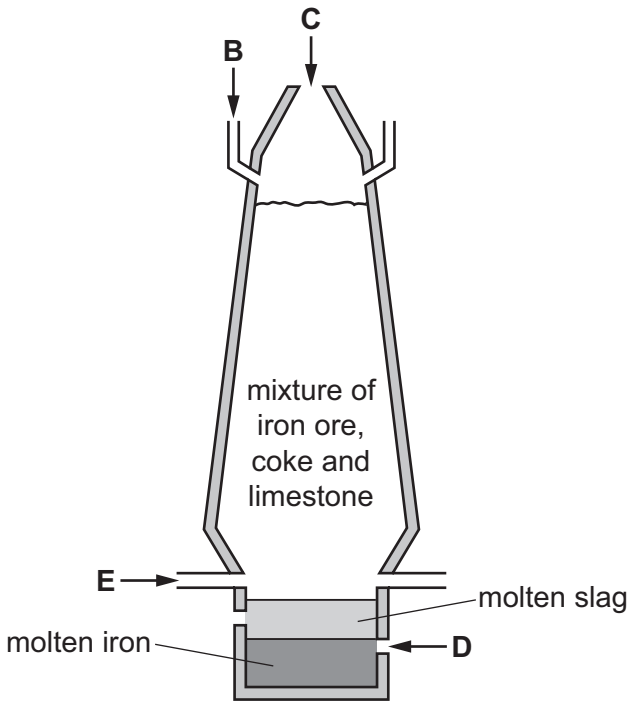
Complete the table to calculate the relative molecular mass of compound **A**.

| type of atom | number of atoms | relative atomic mass | |
|---|---|---|---|
| carbon | 3 | 12 | $3 \times 12 = 36$ |
| hydrogen | | 1 | |
| oxygen | | 16 | |

relative molecular mass = .....
[2]

[Total: 9]

**3** The diagram shows a blast furnace used in the extraction of iron.




**(a)** Air is blown into the furnace.

State which letter on the diagram, **B**, **C**, **D** or **E**, shows where air is blown into the furnace.

..... [1]

**(b) (i)** Complete the chemical equation for the reduction of iron(III) oxide in the blast furnace.

$$Fe_2O_3 + 3C \rightarrow .....Fe + .....CO$$ [2]

**(ii)** Explain how this equation shows that iron(III) oxide is reduced.

..... [1]

**(c)** Calcium carbonate (limestone) is added to the blast furnace.
The calcium carbonate undergoes thermal decomposition.

**(i)** Complete the word equation for this reaction.

| | | | | |
|---|---|---|---|---|
| calcium carbonate | → | ..... ..... | + | ..... ..... |

[2]

**(ii)** One of the products of this reaction reacts with impurities in the iron to form slag.

Use the information in the diagram to suggest how you know that molten slag is less dense than molten iron.

..... [1]

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**(d) (i)** Use words from the list to complete these sentences about how steel is made from iron.

**acidic basic chlorides methane neutral**

**nitrogen oxides oxygen sulfates**

A gas is blown through the molten iron. The name of this gas is ..... .

Acidic gases are formed. These acidic gases react with ..... ..... .
[3]

**(ii)** State **one** use of mild steel.

..... [1]

**(iii)** Metals such as chromium are added to iron to make stainless steel.

The symbol for an isotope of chromium is shown.

$^{53}_{24}Cr$

Deduce the number of electrons, neutrons and protons in one atom of this isotope of chromium.

number of electrons .....

number of neutrons .....

number of protons .....
[3]

**(e)** Chromium conducts electricity and is shiny.

Give two **other** physical properties of chromium that are characteristic of all metals.

1 .....

2 .....
[2]

[Total: 16]

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**[Turn over**

**4** The table shows some properties of the Group I elements.

| element | melting point / °C | density in g / cm$^3$ | observations during reaction with water |
|---|---|---|---|
| lithium | 181 | | slow bubbling no flame |
| sodium | 98 | | rapid bubbling no flame |
| potassium | 63 | 0.86 | rapid bubbling lilac flame |
| rubidium | | 1.53 | |
| caesium | 29 | 1.88 | explodes |

**(a) (i)** Complete the table by predicting:

- the melting point of rubidium
- the density of lithium. [2]

**(ii)** Predict the observations when rubidium reacts with water.

.....

..... [1]

**(b)** Deduce the electronic structure of potassium.
Use the Periodic Table to help you.

..... [1]

**(c)** Lithium reacts with water to produce aqueous lithium hydroxide and a gas which 'pops' with a lighted splint.

**(i)** Name the gas which 'pops' with a lighted splint.

..... [1]

**(ii)** Choose **one** pH value from the list that best describes the pH of aqueous lithium hydroxide.

Draw a circle around the correct answer.

**pH 2** **pH 5** **pH 7** **pH 13** [1]

**(iii)** Lithium reacts with nitrogen.

Complete the chemical equation for this reaction.

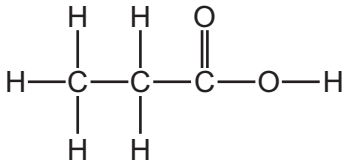
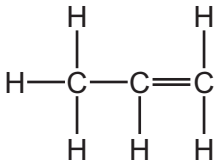
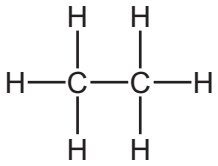
$$\text{.....Li} + N_2 \rightarrow \text{.....}Li_3N$$ [2]

[Total: 8]

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**Question 5 starts on the next page.**

**5** The table shows the structures of some organic compounds.

| compound | structure of compound | homologous series |
|---|---|---|
| **G** |  | carboxylic acid |
| **H** |  | |
| **J** |  | |

**(a)** Complete the table by naming the homologous series.
The first one has been done for you. [2]

**(b)** Draw the structure of a compound containing two carbon atoms which belongs to the same homologous series as compound **H**.
Show all of the atoms and all of the bonds.

[1]

**(c)** State which compound in the table is an unsaturated hydrocarbon.
Explain your answer.

.....

..... [1]

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**(d)** State which compound in the table reacts with aqueous sodium hydroxide.
Explain your answer.

.....

..... [1]

**(e)** State the names of the **two** compounds formed during the complete combustion of compound **J**.

..... and ..... [2]

**(f)** Compound **H** can be polymerised.

**(i)** State the general name given to the small units which join together to form a polymer.

..... [1]

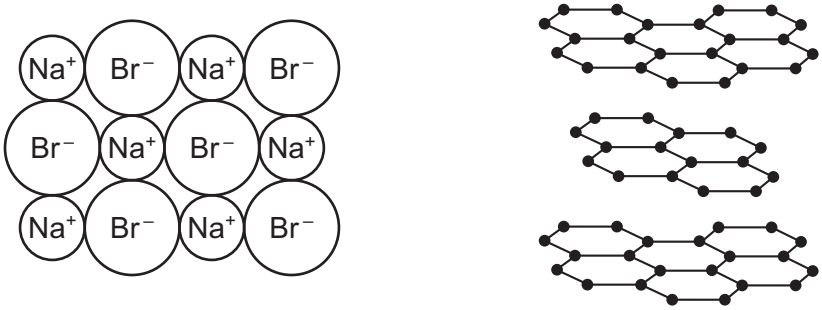
**(ii)** *Terylene* is also a polymer.

Give **one** use of *Terylene*.

..... [1]

[Total: 9]

**6** The diagram shows part of the structures of sodium bromide and graphite at room temperature and pressure.




**(a)** Describe the physical properties of these substances in terms of:

- volatility

sodium bromide .....

graphite .....

- solubility in water

sodium bromide .....

graphite .....

- electrical conductivity when solid.

sodium bromide .....

graphite .....

[5]

**(b)** When dilute sulfuric acid is electrolysed using inert electrodes, oxygen gas is produced at the positive electrode.

Name the gas produced at the negative electrode.

..... [1]

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**(c)** Aqueous sodium bromide reacts with aqueous chlorine.

**(i)** Complete the word equation for this reaction.

| | | | | | | |
|---|---|---|---|---|---|---|
| sodium bromide | + | chlorine | → | ..... ..... | + | ..... |

[2]

**(ii)** Explain in terms of the reactivity of the halogens why aqueous sodium chloride does **not** react with aqueous bromine.

.....

..... [1]

[Total: 9]

**7** This question is about nitrogen and compounds of nitrogen.

**(a)** When nitrogen is cooled to below –196 °C it changes state from gas to liquid.

**(i)** Name the change of state from gas to liquid.

..... [1]

**(ii)** Use the kinetic particle theory to describe the differences between nitrogen gas and liquid nitrogen in terms of:

- the separation of the particles

.....

.....

.....

- the motion of the particles.

.....

.....

.....

[4]

**(b)** Oxides of nitrogen are pollutants in the air.

**(i)** State **one** source of oxides of nitrogen in the air.

..... [1]

**(ii)** Oxides of nitrogen contribute to acid rain.

Give **one** adverse effect of acid rain on buildings.

..... [1]

**(c)** Nitric acid contains the nitrate ion.

**(i)** Use words from the list to complete the sentences to describe the test for nitrate ions.

**aluminium** **ammonia** **chloride** **copper**

**hydroxide** **iron** **oxygen** **sulfate**

Put the sample in a test-tube then add aqueous sodium ..... .

Then add ..... .

Warm gently. A gas is produced. The name of this gas is ..... .

[3]

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**(ii)** Nitric acid reacts with calcium carbonate.

Complete the word equation for this reaction.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| nitric acid | + | calcium carbonate | → | ..... ..... | + | ..... ..... | + | ..... |

[3]

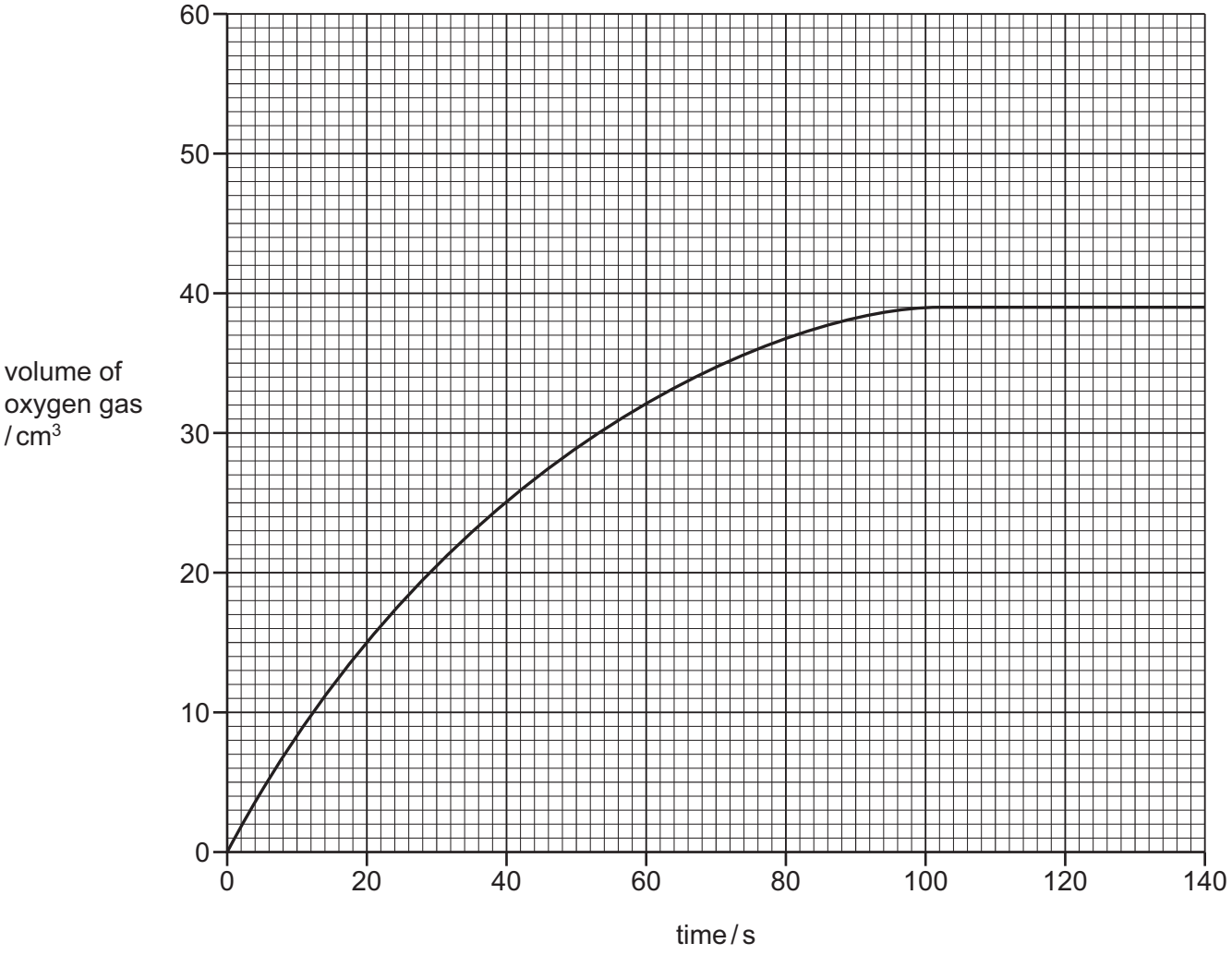
[Total: 13]

**8** The rate of decomposition of aqueous hydrogen peroxide, $H_2O_2$, is increased by an enzyme.

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

The rate of reaction is found by measuring the volume of oxygen gas given off as the reaction proceeds.

The results are shown on the graph.




**(a) (i)** Deduce the volume of oxygen gas released when the reaction is complete.

volume = ..... $cm^3$ [1]

**(ii)** Deduce the volume of oxygen gas produced 50 seconds from the start of the reaction.

volume = ..... $cm^3$ [1]

**(b)** The experiment was repeated using hydrogen peroxide of a higher concentration.

All other conditions stayed the same.

Draw a line **on the grid** to show how the volume of oxygen changes with time when hydrogen peroxide of a higher concentration is used. [2]

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**(c)** Describe the effect each of the following has on the rate of decomposition of hydrogen peroxide.

- The reaction is carried out at a lower temperature.

All other conditions stay the same.

.....

- The reaction is carried out without an enzyme.

All other conditions stay the same.

.....

[2]

**(d)** Some metal oxides catalyse the decomposition of hydrogen peroxide.

The table shows the time taken to produce 20 $cm^3$ of oxygen gas using three different metal oxide powders as catalysts.

All other conditions stay the same.

| metal oxide | time taken to produce 20 $cm^3$ of oxygen gas / s |
|---|---|
| iron(III) oxide | 26 |
| lead(IV) oxide | 12 |
| manganese(IV) oxide | 15 |

**(i)** Put the three oxides in order of their ability to catalyse the reaction.
Put the **best** catalyst first.

best catalyst ⟶ worst catalyst

[1]

**(ii)** The experiments with the metal oxide catalysts used powdered oxide.

Describe the effect on the rate of decomposition of hydrogen peroxide when large pieces of catalyst are used instead of powdered catalyst.

All other conditions stay the same.

..... [1]

[Total: 8]

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## The Periodic Table of Elements

| Group | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I | II | | | | | | | | | | | III | IV | V | VI | VII | VIII |
| | | | | | | | 1 H hydrogen 1 | | | | | | | | | | 2 He helium 4 |
| 3 Li lithium 7 | 4 Be beryllium 9 | | | | | | | | | | | 5 B boron 11 | 6 C carbon 12 | 7 N nitrogen 14 | 8 O oxygen 16 | 9 F fluorine 19 | 10 Ne neon 20 |
| 11 Na sodium 23 | 12 Mg magnesium 24 | | | | | | | | | | | 13 Al aluminium 27 | 14 Si silicon 28 | 15 P phosphorus 31 | 16 S sulfur 32 | 17 Cl chlorine 35.5 | 18 Ar argon 40 |
| 19 K potassium 39 | 20 Ca calcium 40 | 21 Sc scandium 45 | 22 Ti titanium 48 | 23 V vanadium 51 | 24 Cr chromium 52 | 25 Mn manganese 55 | 26 Fe iron 56 | 27 Co cobalt 59 | 28 Ni nickel 59 | 29 Cu copper 64 | 30 Zn zinc 65 | 31 Ga gallium 70 | 32 Ge germanium 73 | 33 As arsenic 75 | 34 Se selenium 79 | 35 Br bromine 80 | 36 Kr krypton 84 |
| 37 Rb rubidium 85 | 38 Sr strontium 88 | 39 Y yttrium 89 | 40 Zr zirconium 91 | 41 Nb niobium 93 | 42 Mo molybdenum 96 | 43 Tc technetium – | 44 Ru ruthenium 101 | 45 Rh rhodium 103 | 46 Pd palladium 106 | 47 Ag silver 108 | 48 Cd cadmium 112 | 49 In indium 115 | 50 Sn tin 119 | 51 Sb antimony 122 | 52 Te tellurium 128 | 53 I iodine 127 | 54 Xe xenon 131 |
| 55 Cs caesium 133 | 56 Ba barium 137 | 57–71 lanthanoids | 72 Hf hafnium 178 | 73 Ta tantalum 181 | 74 W tungsten 184 | 75 Re rhenium 186 | 76 Os osmium 190 | 77 Ir iridium 192 | 78 Pt platinum 195 | 79 Au gold 197 | 80 Hg mercury 201 | 81 Tl thallium 204 | 82 Pb lead 207 | 83 Bi bismuth 209 | 84 Po polonium – | 85 At astatine – | 86 Rn radon – |
| 87 Fr francium – | 88 Ra radium – | 89–103 actinoids | 104 Rf rutherfordium – | 105 Db dubnium – | 106 Sg seaborgium – | 107 Bh bohrium – | 108 Hs hassium – | 109 Mt meitnerium – | 110 Ds darmstadtium – | 111 Rg roentgenium – | 112 Cn copernicium – | | 114 Fl flerovium – | | 116 Lv livermorium – | | |

**Key**

atomic number
atomic symbol
name
relative atomic mass

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| lanthanoids | 57 La lanthanum 139 | 58 Ce cerium 140 | 59 Pr praseodymium 141 | 60 Nd neodymium 144 | 61 Pm promethium – | 62 Sm samarium 150 | 63 Eu europium 152 | 64 Gd gadolinium 157 | 65 Tb terbium 159 | 66 Dy dysprosium 163 | 67 Ho holmium 165 | 68 Er erbium 167 | 69 Tm thulium 169 | 70 Yb ytterbium 173 | 71 Lu lutetium 175 |
| actinoids | 89 Ac actinium – | 90 Th thorium 232 | 91 Pa protactinium 231 | 92 U uranium 238 | 93 Np neptunium – | 94 Pu plutonium – | 95 Am americium – | 96 Cm curium – | 97 Bk berkelium – | 98 Cf californium – | 99 Es einsteinium – | 100 Fm fermium – | 101 Md mendelevium – | 102 No nobelium – | 103 Lr lawrencium – |

The volume of one mole of any gas is 24 $dm^3$ at room temperature and pressure (r.t.p.).